The quest for the Soldier's Rest: Combining anthropological and archaeochemical approaches to study social and occupational diversity in the Medieval graveyard of San Andrés de Arroyo (Palencia, Spain)

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ABSTRACT

The monastery of San Andrés de Arroyo (established in 1181) is one the best examples of Cistercian architecture in the Spanish region of Castilla y León. In this study, strontium isotope ratios were used to study the population of the recently excavated graveyard of this monastery. Twenty-nine individuals (of which 13 had preserved teeth) found in burials from the 13th and 14th centuries were subjected to analysis. Enamel $^{87}Sr/^{86}Sr$ ratio values obtained by using a multicollector ICP-MS instrument were used to distinguish between local and non-local individuals. Additionally, an anthropological study based on entheseal changes and other paleopathological conditions was carried out in all the exhumed individuals. This combined data allowed us to define the chemical and osteological diversity of a Medieval Spanish monastery and its surrounding village. Among the usual profiles for a rural society, two individuals, both showing strong indications of being foreign to the area, were found to have evidence of physical activities compatible with military training and activity. The present study can be considered as the first experimental indication that during the 13th and 14th centuries Spanish monasteries served as a last refuge for soldiers, which is compatible with historical records and previous indirect evidences.

Keywords: Strontium isotope analysis, Entheseal changes, Bone, Teeth, MC-ICP-MS.

INTRODUCTION

Strontium isotope analysis has provided useful and fascinating information about human movements and origins since Ericson (1985) introduced this methodology in the archaeological field. Within the last 30 years, its use has successfully elucidated human mobility and migration in different regions of the world (Ezzo et al., 1997; Giblin, 2009; Montgomery et al., 2005; Tung and Knudson, 2011). As human dispersal is usually non-random and biased among sexual, cultural and social strata (Boyd and Richerson, 2009; Heyer et al., 2012), bioarchaeologists need additional information at the individual level in order to properly interpret migratory events implicating historical populations. For this purpose scholars from different fields have used, as potential markers of activity, the entheses (referred to the skeletal attachment sites of muscles, ligaments and joint capsule) and the changes that these structures undergo during the life of a given individual. Although the analysis and interpretation of entheseal changes (EC) is blurred by their multifactorial aetiology, these features are supposed to reflect the physical activity (in terms of intensity and type) of ancient populations. Their skeleton location and degree of development give an indication of habitual activities involving specific muscles or groups of muscles (Godde and Taylor, 2011). EC have been used to glean cultural behaviour (Foster et al., 2015; Lieverse et al. 2011; Molnar, 2006; Weiss, 2014), to infer differences related to labour and professions (Al-Oumaoui et al., 2004; Dutour, 1986; Kennedy, 1983; Hawkey and Merbs, 1995; Mariotti et al., 2007; Molnar, 2006; Villotte et al., 2010b; Havelková et al., 2011; Palmer et al., 2014; Santana-Cabrera et al., 2015) and to define changes in muscular activity along the evolutionary history of the human lineage (Drapeau, 2008; Milella, 2014).

This paper presents the results of novel research combining, for the first time, both approaches (strontium isotope ratios and entheseal changes). The goals of this research were: (i) to identify possible non-local individuals; and, (ii) to study bio-cultural aspects such as the reconstruction of possible past life styles. For such a purpose, the population of the graveyard of the Spanish Cistercian monastery of San Andrés de Arroyo was examined.

Strontium isotope ratios

The amounts of ^{84}Sr, ^{86}Sr and ^{88}Sr isotopes are constant in nature while ^{87}Sr increases with time as it is formed by the radioactive β-decay of rubidium (^{87}Rb, $t_{1/2} = 4.88 \times 10^{10}$ years) (Faure, 1986). Variation in strontium isotope composition in natural materials is conventionally expressed as the ^{87}Sr/^{86}Sr isotope ratio. If rubidium and strontium are incorporated into a mineral or rock at its formation and the system remains closed with respect to those elements, then the amount of ^{87}Sr increases over time as radioactive ^{87}Rb decays, while the amounts of ^{84}Sr, ^{86}Sr and ^{88}Sr remain constant. Therefore, in general, older rocks will have higher ^{87}Sr/^{86}Sr ratios than younger ones with the same initial Rb/Sr ratio (Capo et al., 1998). The strontium isotopic signature of a given geological region is transferred from bedrock through soils and the food chain into the animal/human skeleton, substituting calcium in the hydroxyapatite lattice (Ericson, 1985; Price et al., 1994). For individuals who consumed locally-grown food, the strontium isotope ratios found in their skeletal tissue will reflect their living region when their tooth enamel or bone was formed. Enamel is formed during childhood and is scarcely modified after its mineralisation (Hillson, 1996). As a result, strontium isotope ratios in enamel reflect childhood residence, if local foodstuffs were consumed, while bone and dentine continually regenerate and incorporate strontium (Parfitt, 1983), reflecting place of residence during the last decades of life as long as local foods were consumed (Price et al., 2002). For each type of tooth, age ranges for formation, from initial root/crown calcification to apex closure, are: I1: 4-5 years; I2: 4-5 years; C: 6-7 years; PM1: 5-6 years; PM2: 6-7 years; M1: 2.5- 3 years; M2: 7-8 years; M3: 12-16 years (Nolla, 1960; Moorrees et al., 1963; Demirjian et al., 1973). While some intrapopulation variability exists, these ranges are conservative and homogeneous for maxilla and mandible (Chaillet and Demirjian, 2004; Chaillet et al., 2004).

Strontium isotope analysis is a powerful technique that can supply provenance information directly from the human skeleton. However, in the majority of cases, diagenetic alteration does occur and it does not proceed simply by the addition of soil derived strontium, but involves partial exchange with the original biogenic material (Trickett et al., 2003). As Montgomery (2010) pointed out, although it would be very useful to use bone to extend the period of life for which strontium isotope data can be obtained, and methods have been suggested for the removal of diagenetic strontium from bone (Sillen and Legeros, 1991; Sillen and Sealy, 1995), there are still major concerns over such data unless it is used to simply provide information about the local biosphere strontium isotope ratios (Montgomery, 2002; Montgomery et al., 2007; Evans et al., 2010).

Entheseal changes (EC)

Activity-related stress refers to any activity that causes repetitive and/or regular movements or patterns of movements that exert stress on the musculoskeletal system (Alves Cardoso and Henderson, 2010; Henderson et al., 2013). In this sense, it is important to bear in mind that EC are not necessarily the result of a heavy work but more the consequence of repetitive work. For many authors, a link can be established between habitual physical activities during ontogeny and EC (Dutour, 1986; Eshed et al., 2004; Hawkey and Merbs, 1995; Kennedy, 1983; Niinimäki, 2012; Weiss, 2007), that should be understood as any deviation from normal anatomy at entheses, or area where a muscle, a ligament or a tendon attaches (Benjamin et al., 2002). Hawkey and Merbs (1995) defined them as marks that occur where muscle, tendon or ligament inserts onto the periosteum and into the underlying bony cortex. It is widely accepted that EC reflect the effect of muscle usage throughout the course of life. However, factors such as the age (Milella et al., 2012; Henderson, 2013; Niinimäki and Baiges Sotos, 2013; Takigawa, 2014; Schrader, 2015), sexual differences due to the existing gender-based differences between endocrine and metabolic systems (Havelková et al., 2013) alongside the particular anatomy of the attachment site have been claimed to be related with the level of the EC expression (Villotte et al., 2010a; Milella et al., 2012). From a medical point of view, EC can be induced by numerous conditions, ranging from pathological to behavioural (Jurmain, 2009). Therefore, it is necessary to take into account all the possible etiological factors that can influence the development of EC as, for example, traumatisms (fractures, amputations, luxations, etc.), some pathologies (spondyloarthropaties, ankylosing spondylitis, tuberculosis, leprosy, etc.), genetic background or even hormonal differences between females and males (Daly, 1994; Sumnik et al., 2006, Foster et al., 2014). So although EC have been used to infer patterns of physical activity, it is clear that, even nowadays, they are poorly understood (Villotte and Knüsel, 2014).

The San Andrés de Arroyo Monastery

The Cistercian Order was founded by Saint Robert of Molesme in 1098. This congregation was born in Cîteaux (Cister), in the diocese of Chalon-sur-Saône, which nowadays belongs to Dijon (France). Since the 12th century, it played an important role in Spanish religious history, with the San Andrés de Arroyo Monastery being a prime example of rural Cistercian architecture. This enclosed female monastery is located in the municipal district of Santibáñez de Ecla (latitude 42º 42´N; longitude 4º 22´W) in the northern part of the Spanish province of Palencia (Figure 1). Although the foundation date of the monastery is not clear, it is assumed that it was founded in 1181 by the Countess Mencía de Lara (Almaraz, 1900). This leads to the theory that the construction workings started at the end of the 12th century, as the monastery chapel was consecrated in 1222. The monastery was finished within the 14th century, although many works and refurbishments, which conferred its current aspect, were carried out during the following centuries (Gutiérrez Pajares, 1993).

According to the Cistercian premises, the life of the members of the monastery was centred on the cloister. Thus, the rooms of the Cistercian sisters were located to the east of the cloister while the rooms of the converted Muslims and Jews occupied the western part (Cocheril, 1964). The chapel, situated to the north of the cloister as the Cistercian premises require, was built throughout the 13th century. The Lobby of the Faithful (a room typical of female monasteries), which is immediately located to the north of the nave of the chapel, was used as a clinic until the modern period. Since then, it has been used to divide the parish cult from the monastic rituals (Figure 2). Like the Lobby of the Faithful, the North Hall belongs to the initial core of the monastery and they were built between the 13th and 14th century. In spite of the fact that its utility is not clear, it could have been used as meeting room or place of voluntary retreat for noble women (Gutiérrez Pajares, 1993). On the other hand, it is not exactly known when the converted stopped living in the western wing of the cloister, although it is clear that this population disappeared in the 17th century, as all these rooms were remodelled and transformed into a granary in 1693. Despite the fact that the monastery has never been abandoned since its foundation, the state in which this building was at the beginning of the 20th century, made necessary interventions in order to preserve and renew some structures (San Gregorio Hernández et al., 2009). Since this moment, all the renovation works have been promoted by the regional government (Junta de Castilla y León). The last one, which took place between 2007 and 2008 with the aim of renewing the granary, the courtyard, the North Hall and the Lobby of the Faithful, prompted the finding of several human remains which are subjected to study in the present work.

Archaeological excavations

The granary

Architecturally, the granary suffered numerous transformations since it was first built in the 12th century. During the 2007-2008 archaeological campaign, a dozen tombs were found in this building of the monastery. Sarcophagi (mainly made out of limestone) and sandstone cists shared here the same burial complex. While the coexistence of both kind of burials is not rare in this area of Spain (Domínguez Bolaños and Nuño González, 2003; Morlote et al., 2005), it is indeed more common to find them separately. Sarcophagi were usually reserved for people of noble background due to its high cost while sandstone cists were the only funeral practice in most villages, forming entire necropoleis. As all the different burials found at the monastery, the tombs from the granary are displayed with E-W orientation according to Christian rituals. The higher antiquity of the burials in relation to the granary, which was built between the 16th and 17th centuries, can be certified as they were found under the base of the walls of this building. Moreover, the typology of the sarcophagi and cists can be clearly ascribed to a period between the last decades of the 13th century and the first half of the 14th century (San Gregorio Hernández et al., 2009). Among all these findings, four sarcophagi were outlined against the rest. They were externally trapezoidal with an anthropomorphic profile on the inside. Surprisingly, simple graves, the most common burials during the Middle Ages, were not present at all. However, it is not possible to discard their existence as the dimensions of this graveyard are unknown because only the burials beneath the parts subjected to refurbishment were excavated (San Gregorio Hernández et al., 2009).

The courtyard

The archaeological excavations in the courtyard were carried out in the northern part of the North Hall and the Lobby of the Faithful (Figure 2). These excavations allowed finding 18 burials. The typology of this area is the most varied of the monastery with three out of the four typical funeral burials of this region of Spain. Sarcophagi, cists and simple graves were found but not anthropomorphic tombs excavated in rocks, uncommon in this region anyway because of the clayey terrain (Nuño González, 2002). The sarcophagi of the courtyard are similar to the granary ones, being trapezoidal to the exterior and anthropomorphic to the inner part. Simple graves consisted on a pit on the ground in which the body was placed and covered again with the same soil. It is worth saying that there is no special distribution of the burials, although the most elaborated tombs, like cists and sarcophagi, seem to be located in the southern part of the courtyard and thus, closer to the chapel. This may suggest that people with higher purchasing power could have paid for sandstone cists or sarcophagi in order to be buried next to the chapel (Van Den Eynde Ceturi, 2002). However, it is important to take into account that, due to the presence of numerous rocky outcrops in the area, it was not difficult to obtain the raw material to make these tombs. Moreover, there are some cases in which tombs were made with ashlars that were probably obtained from previous constructions carried out in the monastery throughout these centuries. In this burial complex, there are few archaeological evidences to aid chronological dating, though some ceramics were found and have been dated as 13th century. According to this chronology, as well as the general characteristics of this graveyard, it could be feasible to establish a relationship with the burials of the granary. Due to numerous similarities between them, it is possible to think that both places could have been used at the same time or, at least, in a period close in time (San Gregorio Hernández et al., 2009).

The North Hall

The construction of the North Hall building took place between the end of the 13th century and the first years of the 14th century according to its structure and decorations, as well as for its 14th century inscriptions (Gutiérrez Pajares, 1993). In this case, 17 tombs were found. The majority are simple graves though three sandstone cists are also present. The finding of ceramic remains in this area has permitted to date these burials as 13th century. Bearing in mind this dating, some typological similarities, and the proximity to the tombs found in the courtyard (Figure 2), it would be possible to think that all these burials formed part of the same funeral complex (San Gregorio Hernández et al., 2009).

The Lobby of the Faithful

This area is particularly interesting for the great density of burials that are present. In fact, a total of 26 simple graves were found in 12 m^2. Such a high concentration of tombs might be due to the wish of the people to be buried as closest as possible to the chapel. In this graveyard, the presence of artefacts that could be used for a reliable dating is very scarce. In this sense, only two small batches of ceramics were found and both belong, again, to the 13^{th} century (San Gregorio Hernández et al., 2009). This dating contrasts with the data obtained by the company UNOVEINTE S.L. (2007) as a copper maravedí (old Spanish coin) from the 15th-16th century was found in the hand of one skeleton who was buried in a grave in the opposite side of the chapel. It is very complicated to obtain a conclusion regarding this chronological difference but it would be possible to cautiously think that places close to the chapel were previously occupied.

MATERIALS AND METHODS

Samples

Osseous material was directly provided by the archaeologists in charge of the excavations, under responsibility of the Regional Government of Castilla y León. All the skeletons subjected to study were found in burials dated from the 13^{th} to the 14^{th} centuries, which corresponds to the Spanish High Middle Ages. After the archaeological intervention, 29 individuals were analysed (6 at the granary, 7 at the courtyard, 6 at the North Hall and 10 at the Lobby of the Faithful), of which 13 had preserved their teeth. Table 1 displays the sex, age, presence and type of teeth and, burial type and location for each studied individual.

Additionally, 7 domestic faunal samples, which represent the total number of animal samples found during the 2007-2008 archaeological campaign, were also analysed in order to define, along with the human bone samples, the $^{87}Sr/^{86}Sr$ local range (Buzon et al., 2007; Montgomery et al., 2003). These faunal samples were defined as S-B 01 (sheep ischium), S-B 02 (sheep mandible), S-B 03 (sheep metatarsal), S-B 04 (sheep orbital), S-B 05 (sheep vertebra), C-B 01 (cow metatarsus) and S-T 01 (sheep molar tooth).

Sex and age determination

Biological sex determination for all individuals over 20 years old was based on methods which relied on classical morphological parameters of sexual dimorphism in the pelvis and cranial morphological aspects (Buikstra and Ubelaker, 1994; Byers, 2005). Estimating the age-at-death of an adult skeleton is a critical component of forensic studies. The assessment of it was based on the main macroscopic changes of the pelvis with the following criteria: metamorphosis of the pubic symphysis (Brooks and Suchey, 1990; Rissech et al., 2012; Wink, 2014), changes of the auricular surface of the ilium (Lovejoy et al., 1985) and, stages of tooth attrition (Hillson, 1996). The general presence of degenerative changes of the skeleton was also considered. The use of cranial closure for age determination is considered very controversial because its results are largely unreliable and irreproducible, with a medium to poor correlation between suture closure and age (Hershkovitz et al., 1997; Galera et al., 1998).

Recording of entheseal changes data

Notwithstanding the questioned possibility to establish a relation between EC and activity, some recent studies of EC of skeletons are based on the hypothesis that the first reflect the physical activity of our forebears (Havelková et al., 2013; Henderson, 2013; Lieverse et al. 2009; Lieverse et al. 2013; Villotte and Knüsel, 2014; Schrader, 2015). This is due to the fact that specific movements carried out frequently affect both structure and morphology of entheses (Benjamin and Hillen, 2003; Galtés et al., 2006). But despite it, the relation between muscular activity and EC and the how to better use them for inferring the activity in life is far from being clear. For an extended discussion see Santos et al. (2011) and Henderson and Alves Cardoso (2013) and references therein.

Although several qualitative methods have been developed and proposed for EC recording (Hawkey and Merbs, 1995; Al-Oumaoui et al., 2004; Mariotti et al., 2004, 2007; Villotte, 2006; Alves Cardoso and Henderson, 2010; Villotte et al., 2010a; Henderson et al., 2013), no single method is currently widely accepted (Schrader, 2015). However, many authors agree that one important first step implies the distinction between fibrous and fibrocartilaginous entheses (Benjamin and Ralphs, 1999; Benjamin et al., 2002; Villotte et al., 2010a; Weiss, 2015). Thus, 17 fibrocartilaginous postcranial attachments sites were selected as presented in Table 2 and Table 3. All of them have been assessed in previous studies and reflect the activity of the whole body. To avoid confounding, individuals clearly affected with pathologies along with individuals under 20 years old were excluded from the study. Individuals affected by disease are complicated to assess as entheseal development might be compromised or altered. On the other hand, immature and young individuals are not expected to have overused specific muscles that lead to the formation of bony lesions, and thus they are uninformative. Each individual was included in different categories according to the specific EC found on it. For such a purpose, three out of the four categories of occupations proposed by Villotte et al. (2010a) were used. In each category we give examples of probable activities or trades of these centuries (13th and 14th), always taking into consideration that it is not possible to infer from the interpretation of entheseal changes specific professions or occupations. The three groups here presented are the following: (i) *Group A*. Manual workers like shoemakers, tailors, weavers, home servants, etc.; (ii) *Group B*. Manual workers who carry heavy loads and/or are involved in vigorous tasks, for instance carpenters, masons, rural workers, butchers, bakers, blacksmiths, stone sculpting, metal workers, tanners, etc.; and, (iii) *Group C*. Manual workers, probably involved in vigorous tasks. In this latter case, it is possible to include manual jobs which imply heavy physical labours like soldiers, day labourers, unskilled workers, etc. In the present study, the group related to non-manual workers (like priests, storekeepers or landowners just to cite a few) was discarded as their putative poor physical development is difficult to identify by the proposed EC.

Strontium isotope analysis methodology

<u>Bones</u>

Cortical femora human samples were cut in thin slabs at the Faculty of Geology of the University of Oviedo using a continuous band diamond disc saw (350 mm diameter, 10 mm thick) while animal bones, due to their smaller size, were cut by means of a Dremel drill equipped with a diamond disc saw. In this study, femora bones were used for the determination of strontium isotope ratios because bones with low turnovers are less susceptible to diagenesis than others with rapid turnovers. For the same reason, cortical femora was sampled instead of trabecular (Buikstra et al., 1989; Lambert et al., 1982). X-Ray radiography was used to check the integrity of the femora bones. Due to this, it was possible to detect soil inclusions that might interfere in the biogenic fraction of the bone. Anterior-posterior radiographs were taken at the Hospital Universitario Central de Asturias (HUCA-Oviedo) using a Kodak Industrex AX ready pack film with an exposure time of 10 ms at 10 mA and 90 kV. All the different bone samples were ground in a MM20 ball mill at the Department of Biology of Organisms and Systems of the University of Oviedo. Approximately 0.2 g of bone powder was transferred to PTFE vessels and digested in 5 mL of subboiled HNO_3 and 3 mL of Suprapur H_2O_2 30% using an Ethos 1 Milestone microwave oven. After this pretreatment, the samples were transferred to PTFE vessels and digested in 5 mL of subboiled HNO_3 and 3 mL of Suprapur H_2O_2 30% using an Ethos 1 Milestone microwave oven. Subsequently, the isolation of strontium was performed with a strontium-specific extraction chromatographic resin following the protocol described by De Muynck et al. (2009). Finally, strontium isotope ratio measurements were carried out *via* Inductively Coupled Plasma Mass Spectrometry using a multicollector instrument housed at the University of Oviedo (Thermo Electron Corporation). Experimental intensities at masses 86 and 87 for each run were corrected for the contribution of ^{86}Kr and ^{87}Rb using the reference IUPAC ratios $^{86}Kr/^{83}Kr$ of 1.5025 and $^{87}Rb/^{85}Rb$ of 0.38562 (Berglund and Wieser, 2011). Then, the experimental $^{88}Sr/^{86}Sr$ ratio was calculated and the mass discrimination factor was computed using the exponential model taking the $^{88}Sr/^{86}Sr$ certified value for the standard NIST SRM 987 ($^{88}Sr/^{86}Sr = 8.37861$) as reference. The accuracy and the external precision for the NIST SRM 987 during the MC-ICP-MS measurement session was also monitored, obtaining a 0.71052 ± 0.00006 value (uncertainty is given as standard deviation for n = 50) for the $^{87}Sr/^{86}Sr$ ratio, which is in excellent agreement with the certified value of 0.71034 ± 0.00026.

<u>*Teeth*</u>

Permanent tooth enamel from 13 individuals was sampled using a Dremel drill equipped with a diamond disc saw. Both maxillary and mandibular molars and premolars were preferably sampled. However, they were not always available for all the individuals, as shown in Table 1. Enamel was collected from the occlusal surface to the cemento-enamel junction (CEJ). Although enamel is harder, denser and more inert than bone and, therefore, less susceptible to diagenesis, basically due to its relatively large phosphate crystals (> 1 µm) and its compact structure with little pore spaces (Hillson, 1996; Koch, 1997); approximately 40 mg of enamel was mixed at room temperature with 5 ml of acetic acid 5% and immersed in an ultrasonic bath for 10 minutes to remove possible contaminants (Sillen and Sealy, 1995; Nielsen-Marsh and Hedges, 2000). Once the acetic acid was removed, enamel was rinsed three times with ultrapure water. Afterwards, samples were transferred to flat-bottom Teflon (PFA) screw cap vials and digested in a hot plate with 1 ml of subboiled HNO_3 and 1 ml of Suprapur H_2O_2

(30%) at 110ºC for 30 minutes. Strontium was then isolated and measured by MC-ICP-MS as described above for the bone material.

RESULTS

Strontium isotope ratios

Strontium isotopic data obtained for both human and animal remains are shown in Table 4 and Figure 3. In the case of humans, bone $^{87}Sr/^{86}Sr$ isotope ratio values range from 0.70864 to 0.70946 while tooth enamel values range from 0.70868 to 0.71234. On the other hand, $^{87}Sr/^{86}Sr$ isotope ratio values found in animal bones vary from 0.70861 to 0.70901 while the sheep enamel sample has an $^{87}Sr/^{86}Sr$ value of 0.70890. The bioavailable $^{87}Sr/^{86}Sr$ signature for this region was defined by the human bone samples, whose value is 0.70896 ± 0.00044 (n=29; mean ± 2s.d.). The reliability of this range was supported by determining the strontium isotope ratios in domestic faunal skeletal tissues, as local $^{87}Sr/^{86}Sr$ is also usually determined by local fauna (Price et al., 2002). The obtained range was 0.70884 ± 0.00031 (n=6; mean ± 2s.d.).

Entheseal changes

A detailed study based on musculoskeletal stress markers was also carried out. It is important to stress that, like in the case of strontium isotope analyses, the MSM data should be interpreted with caution as a probable result but never as a final one. However, the combination of both methodologies permits to support each other and, therefore, leads to a more reliable interpretation of the obtained data. As results of this assessment, Table 5 compiles several possible labour-related activities for all the analysed individuals based on their EC, while Table 6 gathers detailed EC data from each individual subjected to study.

In the present study, among all the skeletal remains, 5 females were found (UE 14, UE 251, UE 258, UE 3006 and UE 9004). According to their EC, these individuals could have performed activities demanding little muscular effort, so they should be included preferentially in group A (i.e.: farming, weaving or seamstressing). In the case of males, activities related to a more demanding profession are observed – Group B or Group C- (among others carpentry, blacksmithing or woodcutting trades were probable among the individuals investigated). Regarding to the strontium isotope ratio data displayed in Table 4, the individuals named as UE 108 and UE 114 could be defined as non-locals, so special attention was given to them.

Individuals defined as non-local by strontium isotope ratios

Individual UE 114

This individual is a male who died at the age of 40-50 years. His height was estimated as 168.77 cm by adapting the method described by Konigsberg et al. (2006) to the regression formulae proposed for the Spanish population (Nunes, 1998). The upper extremities present numerous marks of entheseal changes, showing greater development on the right side. This fact indicates a possible preferential use of the right side. Markers related with abduction of the shoulder(supraspinatus and teres minor EC), internal rotation (subscapularis EC) and external rotation (infraspinatus and supraspinatus EC) were observed in both arms (Kapandji, 1987; Palastanga et al., 2007). The anconeus muscle entheseal marker, which extends the forearm at the elbow (Hawkey and Merbs, 1995), is also present. Flexion and extension movements are represented mainly by the brachialis, triceps brachii, biceps brachii and brachioradialis muscles EC in the radius and ulna bones (Nygaard et al., 1983). The elevation of the anconeus flap is only found in the left arm, which would be associated in this case with maintaining an extended position (Athwal et al., 2006). Other observed markers in the UE114 male were associated with supination/pronation and extension/flexion movements of the hand, such as the common origin of wrist extensors and flexors, in the lateral and medial epicondyle of the humerus, respectively (Ettema et al., 1998). In the lower limb remains, the different EC found are related with movements, caused by weight-lifting from a bent-legged position (Capasso et al., 1999), riding horses or standing up for long hours. We want to highlight the finding of the obturator internus entheseal marker in the left femur, although is not included among the 17 EC selected for this work, as it has been associated with hand-to-hand fighting (Bethencourt Alfonso, 1994; Estévez González, 2002). On the whole, the movements indicated by the markers are associated with activities entailing one arm that makes a sudden powerful movement (which would be the right one) and a static arm probably used for holding (which would be left one). Percussion activities as wood chopping, stone sculpting, or metalworking would be compatible with these markers (Capasso et al., 1999; Kennedy, 1989). Archery and warfare activities which involved fighting with an object in one hand, and a protective element in the other one, would also be compatible (Dutour, 1986; Stirland, 1993). It is also interesting to mention that this man shows a traumatism and an injury in the left supraorbital edge of the frontal bone; both caused by a sharp weapon as the area shows remarkable inflammation (Figure 5). This lesion was not fatal for him, since there are clear signs of bone remodeling.

Individual UE 108

These human remains belong to a man over 60 years old at the time of death, with a stature of 173.80 cm (well above the exhumed population average, which is 166.59 ± 5.35 cm). In the upper limb bones, many markers of occupational stress have been found in both sides of the body. Around the shoulder joint, the same UE 114 individual markers appear. This fact can be also interpreted as the consequence of frequent abduction and internal/external rotation movements (Wienker and Wood, 1988). These markers have a distinct bilateralism in their presence as well as in their development degree, except for those found in the proximal end of the humerus (supraspinatus, infraspinatus and subscapularis), which only appear or are more developed on the left bone. Regarding the elbow, there are clear markers of repetitive extensions and flexions of the arm (Kennedy, 1989; Morales Padrón, 1993). In this case, we can see a greater development of the triceps brachii enthesopathy in the left ulna than in the right one; which is a marker related to repeated sudden elbow extensions (Dutour, 1986; Estévez González, 2002). The appearance of the elevation of the anconeus flap in the right side could be related to this marker, as this muscle is associated with a continued expansion of humeroulnar joint (Capasso et al., 1999). All these markers may indicate that the preferred arm for percussion movements was the left, while the right one performed holding or other static actions. In the wrist, the presence of ridges in the dorsal tubercles of both radii should be highlighted, as this is closely related to EC in the wrist flexor and extensors muscles (Kennedy, 1989). This is a sign of the stress experienced by the muscles and tendons of the hands while grasping objects for extended periods of time (Capasso et al., 1999). Despite the fact that the legs of this individual were incomplete, there were many markers of occupational stress that revealed a strong muscle mass in this area. Among them, the great degree of development of the site of insertion of the gluteus medius, should be emphasised. The illiac psoas enthesopathy at its insertion on the lesser trochanter, which is related to hip stability when the individual is in an unstable position, is also observed (Kapandji, 1987). Gluteus medius and minimus enthesopathies on both greater trochanters indicate the habit of standing up for prolonged periods, or the frequent use of movements which require abduction or external/internal hip rotation (Dutour, 1986; Estévez González, 2002). The coupling of all these markers has often been associated with the habit of riding and the awkward posture and muscular tension which arise from it (Capasso and Di Tota, 1996). This hypothesis is strengthened by the presence of the round ligament enthesopathy on the head of both femurs, which is responsible for restricting the flexion movement of the femur when accompanied by the abduction movement (Kapandji, 1987; Kennedy, 1989). This fact has been commonly linked to riding habits by various authors (Dutour, 1986; Estévez González, 2002; Kennedy, 1989). Overall, the movements associated with the markers described for this individual, suggest professional exercises such as blacksmithing or stone sculpting. Additional evidence related to the habit of riding may also suggest military activities (Morales Padrón, 1993). In fact, all of these occupations are not mutually exclusive, as “commoner knights” were a sizeable part of the Christian hosts mobilized during Medieval times in the Iberian Peninsula (Showalter, 1998). These were professional soldiers with a non-noble background which were mustered by a minor feudal lord, and for their ranks King Alphonse X (1221-1284) even recommended to preferentially recruit carpenters, smiths and stonemasons, as “they are skilled for wounding and strong of hand” (Russell, 2001).

DISCUSSION

The presence of different types and places of burials could suggest (at first sight) the possibility of providing information about the status, way of life or labour activities of the different individuals. However, the fact that all burials could have formed part of the same funeral complex makes obtaining conclusions difficult. Although people with higher purchasing power could have paid for sandstone cists or sarcophagi, due to the presence of numerous rocky outcrops in the area, it was not difficult to obtain the raw material to make these tombs. There are some cases in which tombs were made with ashlars that were probably obtained from previous constructions carried out in the monastery throughout centuries. So, from these data, it is not possible to obtain a clear relationship between sandstone cists or sarcophagi and people with a high status. Table 1 shows that sarcophagi were found both at the granary and the courtyard. The granary is far from the chapel when compared to the courtyard. So, once again, it seems that there is no obvious relation between type and place of burial. As already pointed out, it would be possible to cautiously assume that places close to the chapel were previously occupied irrespective of the social condition.

On the other hand, according to the available data, both biological sexes were buried in the different burial places regardless of the type of burial. However, as only five female individuals were analysed, definitive interpretations are difficult to achieve. A particular aspect of the burials is that at the Lobby of the Faithful only simple graves were found. Being this place the closest one to the chapel, this fact strengthens the possibility that this area was first occupied irrespective of the status. To sum up, it is of great importance to be very careful when interpretations regarding spatial and social differentiation within the graveyard site are to be proposed and, therefore, other approaches should be used to understand the San Andrés de Arroyo complex.

As a result, the use of strontium isotope analysis offered the possibility to shed some light on the history of the monastery. First of all, it is important to define the bioavailable $^{87}Sr/^{86}Sr$ signature for a given region, which can be obtained by analysing the human bone samples as previously said. Table 4 and Figure 3 displays the data which permitted to define local $^{87}Sr/^{86}Sr$ range as 0.70896 ± 0.00044 (n=29; mean ± 2s.d.), which is in good agreement with the average value of the different animal bone samples, whose value is 0.70884 ± 0.00031 (n=6; mean ± 2s.d.). This fact strengthens the reliability of the local range here presented. According to the results presented in Table 4 and figure 3, all of the females present strontium isotope values in enamel (when available) that are within the local range. Similarly, the same can be said in the case of males. Although some individuals, like UE 21, UE 22 or UE 265, present slightly higher $^{87}Sr/^{86}Sr$ values, due to the proximity of these data to the limits of the local range, it would not be sensible to state that they were allochthonous.

For this reason, only the individuals named as UE 108 and UE 114, were considered as non-locals as their enamel $^{87}Sr/^{86}Sr$ ratios (UE 108: 0.71234 ± 0.00008; UE 114: 0.71084 ± 0.00012) are clearly different from the defined local range (0.70923). This fact is, without doubt, consequence of an early life in other geological area.

The data provided by the strontium isotope ratios can be supported and better interpreted with the help of musculoskeletal stress markers. Thereby, Table 5 compiles the labour-related activities for all the individuals subjected to analysis, and detailed individual-level information is supplied on Table 6. As can be observed, most of the individuals belong to Group B as expected in a Spanish rural environment during the 13th and 14th centuries. Such a group gathers rural workers and artisans whose occupations meant possible strong physical effort like carpenters, blacksmiths or woodcutters. While Group B is mainly formed by males, Group A is typical of females and includes manual labour tasks that do not involve special use of strength (farmers, weavers, seamstresses, washerwomen, etc.). Although these last activities were linked to the life of nuns ("sisters") in a monastery during the Middle Ages, it is worth taking into account that no entheseal changes related to the monastic life (strictly speaking), like the presence of medial and lateral squatting facets on the tibia and talus, were observed. Nuns should also show a dorsal extension of the joint surface on the first metatarsus and first foot phalanx, as well as a bilaterally facet at the anterior surface of the distal end, due to the hyperflexion of the ankle (Capasso et al., 1999). Moreover, no knee osteoarthritis (typical lesion which is consequence of repetitive flexions and kneeling for daily praying), was observed either. Sisters should also show a dorsal extension of the joint surface on the first metatarsus and first foot phalanx, as well as a bilaterally facet at the anterior surface of the distal end, due to the hyperflexion of the ankle (Capasso et al., 1999). Therefore, according to what has been explained, it is not possible to state that these females were sisters of the Cistercian Order. On the other hand, among all the specimens analysed, special attention was paid to the UE 108 and UE 114 individuals. All the information given by the entheseal changes combined with the strontium isotope ratios data would permit us to assume that these individuals could have been soldiers, at least, during their youth. This hypothesis might be supported by the fact that in the 13th and 14th centuries, the Iberian Peninsula was still immersed in the Spanish Reconquista, a period of almost 800 years in the Middle Ages during which several Christian kingdoms fought and succeeded in retaking the territory conquered by the Muslims, who occupied almost the totality of Iberia between the years 711 and 722 (Lomax, 1978). The presence of these individuals in the graveyard of the San Andrés de Arroyo Monastery is not rare if we consider that monasteries had guest quarters in which people from different origin and social backgrounds were accommodated. Between the 13th and 14th centuries Muslims only controlled the southern part of the Iberian Peninsula (Kingdom of the Almohades; Figure 4), so these individuals could have moved to a more northern place to spend the last years of their lives after fighting for years. EC related to frequent percussion movements and steady holding of heavy objects fit well with the preferred fighting style of Christian hosts during the Reconquista War, based in large numbers of men-at-arms and riders with swords and spears, in which knights required to carry shields at all times under the risk of demotion (García Fuente, 2013). In this sense, in 1900, the Bishop of Palencia, Enrique Almaraz, reported the presence of swords in three sarcophagi found at the chapel of the monastery, suggesting the possibility that these individuals could have been knights (Almaraz, 1900). Additionally, as Powell (1986) pointed out, the crusade, as a vocation, could tap into the powerful lay fascination with the ideals of monastic life, the *vita apostolica* and the *imitatio Christi*. This intertwining was specially powerful in the Christian kingdoms of the Iberian Peninsula, where numerous military orders were created and had an active role in all matters of state until at least the 16th century (Goddard-King, 1921). Religious fervour was also regarded as a strong element of cohesion for militia units, especially for the commoner knights, despised by their noble counterparts but usually admired by the general populace as virtuous icons (García Fuente, 2013). Such a close relationship between faith and the life of soldiers, strengthened the religious view that Crusadeing was a fitting instrument for the moral transformation of the individual Christian and the Christian society as a whole (Powell, 1986).

CONCLUSIONS

San Andrés de Arroyo is regarded as one of the most important Cistercian monasteries in the Spanish region of Castilla y León. In the present study, 29 individuals, who were exhumed during the archaeological campaign that took place during 2007-2008, were subjected to analysis. All studied skeletons were found in burials which were dated as 13th and 14th AD. The use of strontium isotope analysis permitted us to identify 2 individuals who, according to their enamel $^{87}Sr/^{86}Sr$ ratios, clearly spent the first years of their lives in other geological regions. Additionally, a detailed study based on entheseal changes, could connect these individuals to fighting and military activities; supporting a possible past occupation as soldiers during the Spanish Reconquista. On the other hand, the individuals defined as locals, are related with labours included in the named *Group B* like carpentry, blacksmithing or woodcutting trades in the case of males; while farming, weaving or seamstressing (*Group A*) were usually performed by females. The combination of strontium isotope ratios with EC permitted to better define and understand the way of life in the San Andrés de Arroyo monastery, as well as to differentiate between locals and non-locals within the population of this place. Moreover, according to what has been explained, this study can be considered as the first experimental indication that during the 13th and 14th centuries Spanish monasteries served as the last refuge for soldiers, as historians have recently proposed (Pascual Sarría, 2003; Valdeón Baruque, 2006). Therefore, by combining both approaches it would be possible to experimentally corroborate the historical information of a given population, and this methodology should instil confidence in future ancient osteological studies. Although a small part of the monastery was excavated and, therefore, the boundaries of the graveyard beneath it are still unknown; the results presented in this study shed some light on the up to now lack of information about the people buried throughout centuries in this Cistercian building.

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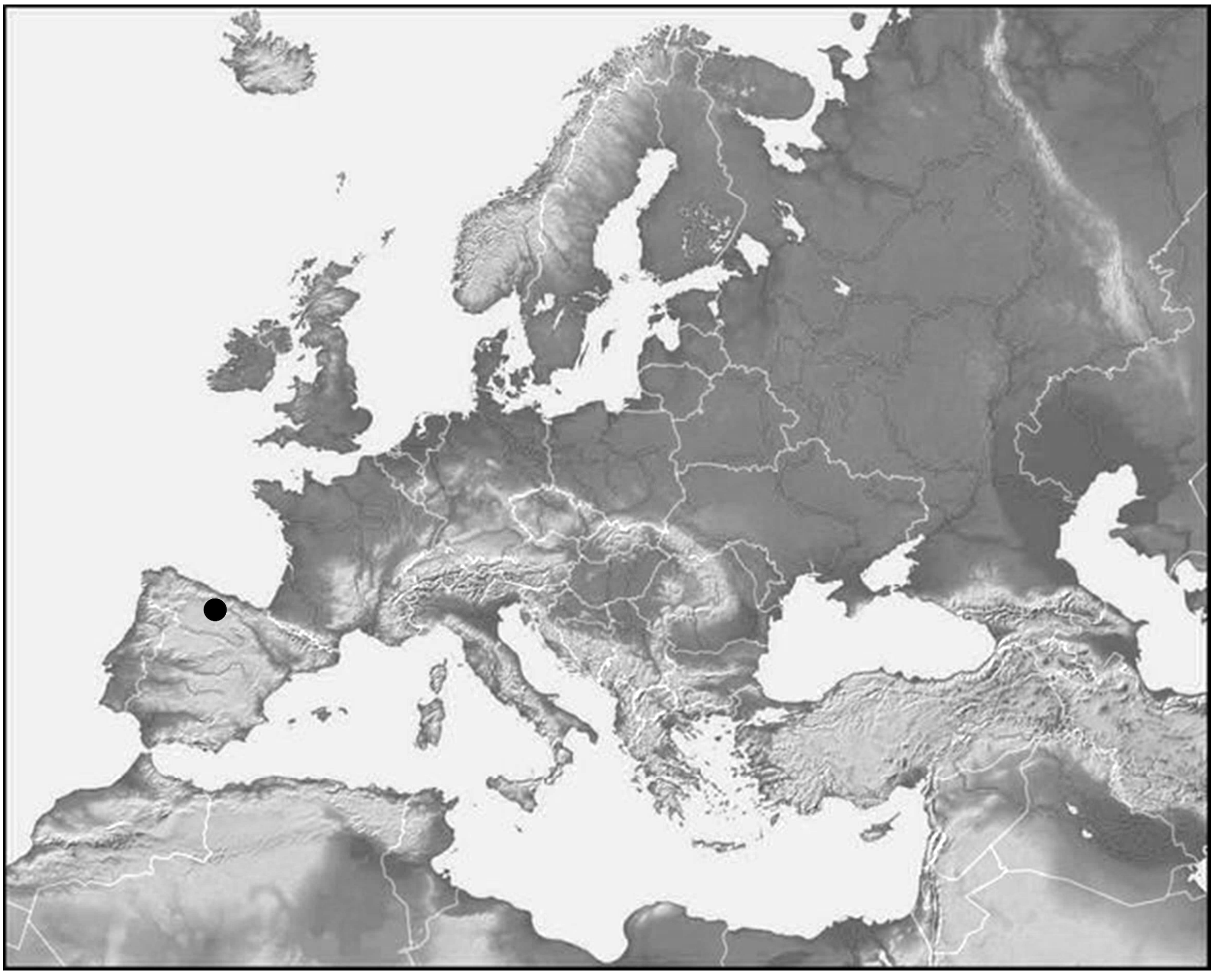

Figure 1. Approximate location of the San Andrés de Arroyo Monastery.

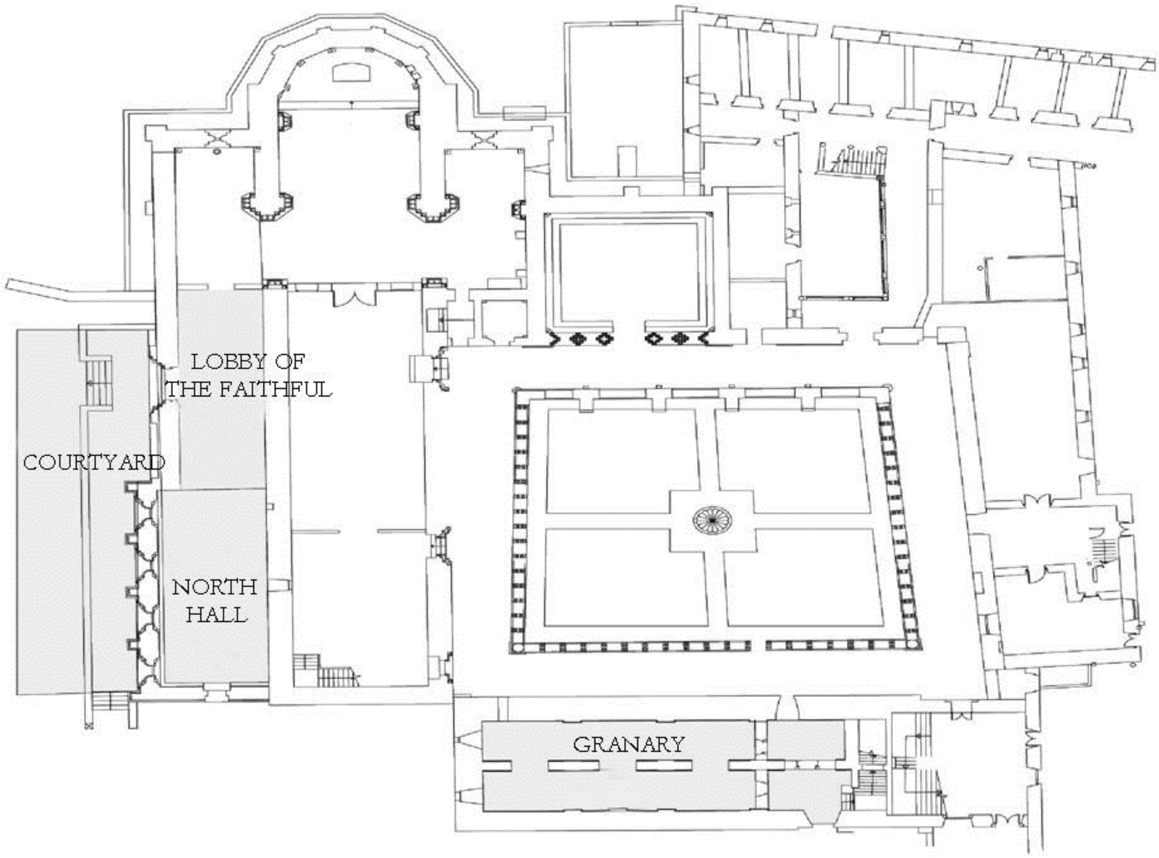

Figure 2. Plan of the San Andrés de Arroyo Monastery. Excavated areas indicated in grey.

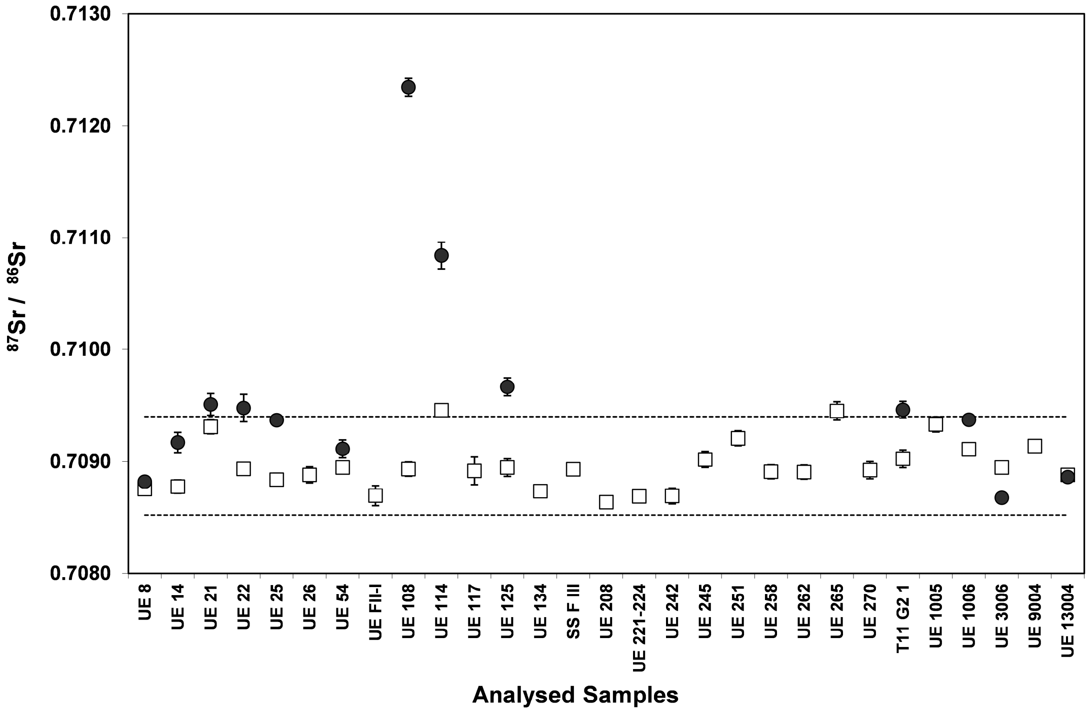

Figure 3. Strontium isotope ratios ($^{87}Sr/^{86}Sr$) for human bone (squares) and teeth (circles) samples found at the San Andrés de Arroyo Monastery. Uncertainty is given as standard deviation. Dash lines refer to local isotope range defined by the bioavailable $^{87}Sr/^{86}Sr$ signature of the human bone samples (0.70896 ± 0.00031) shown in Table 4.

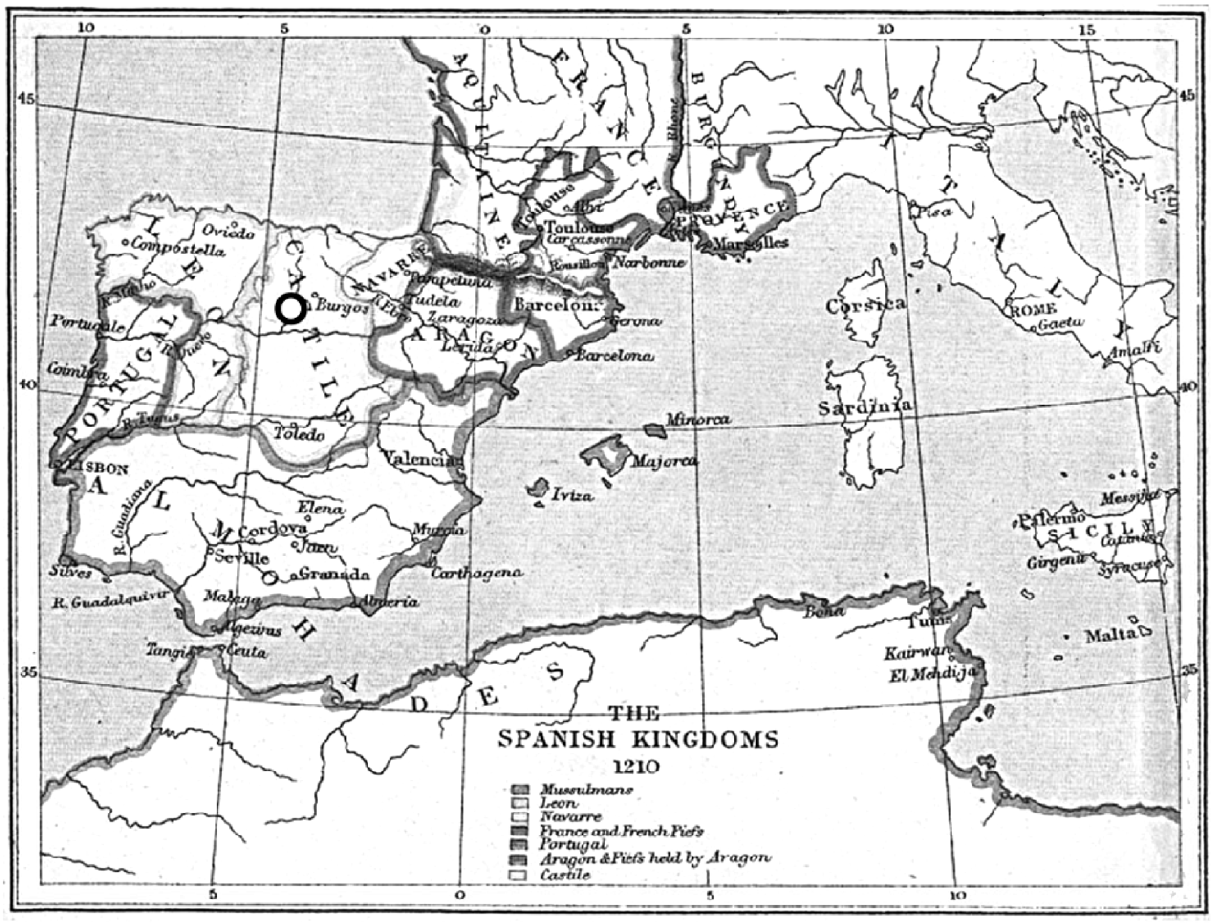

Figure 4. The Spanish Kingdoms in 1210 AD (Freeman, 1903). The black dot represents the approximate location of the San Andrés de Arroyo Monastery.

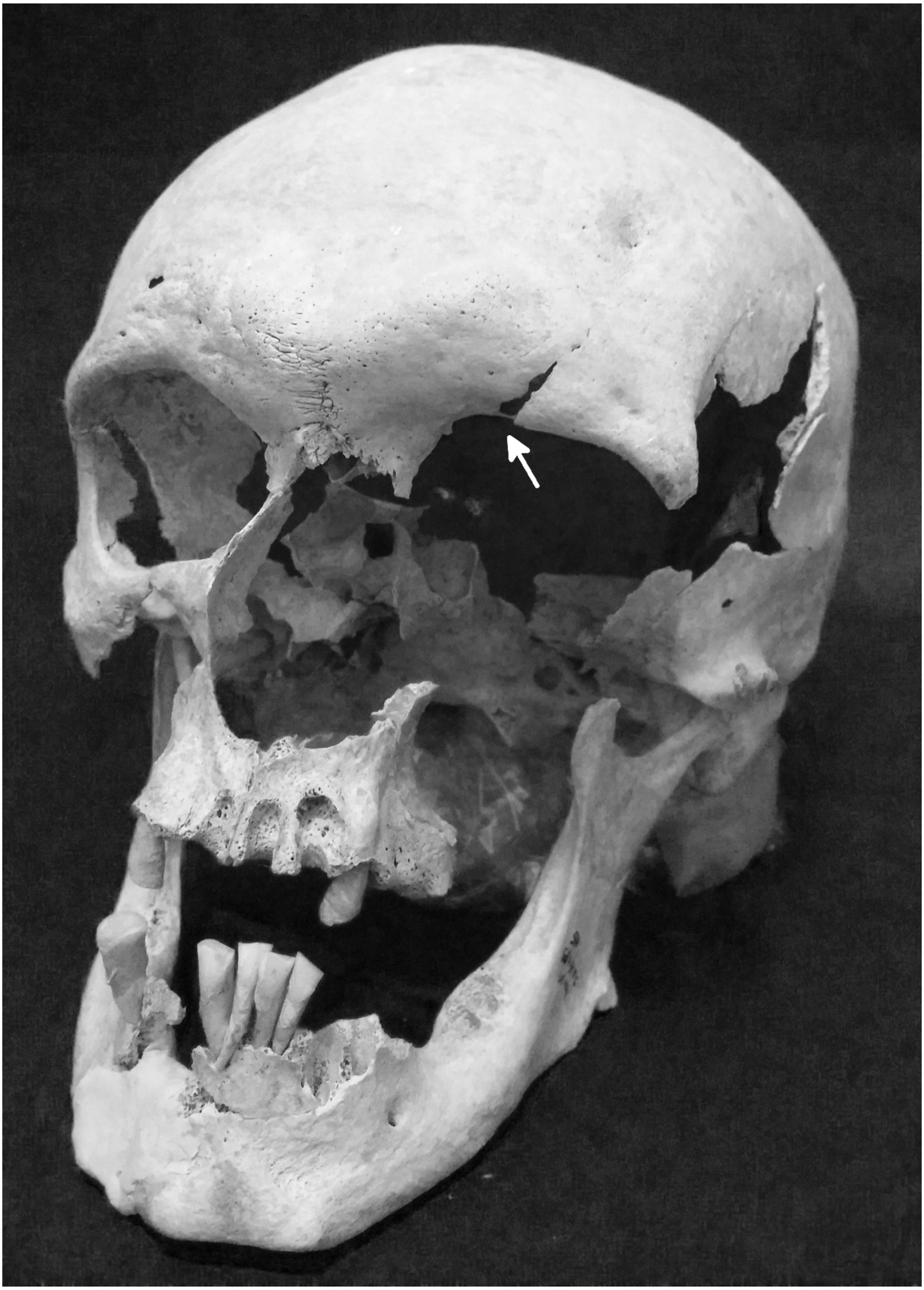

Figure. 5. Skull from male UE 114 showing a swollen fracture from a blade on the left orbit (arrow) with evidence of healing.

Table 1. Analysed individuals are shown including sex (F-female; M-male), age, presence of teeth, burial location and burial type. The burial locations are categorized as CY (courtyard), NH (North Hall), LF (Lobby of the Faithful) and GR (granary), respectively. The burial types are indicated as SA (sarcophagi), CI (cists) and SG (simple graves). The type of tooth is expressed as I (incisor), C (canine), P (premolar) and M (molar). The number indicates the dental piece from the centre of the maxilla/mandible to the distal side.

Specimen number	Burial site	Burial type	Teeth	Sex	Age
UE 8	CY	CI	P2	M	50-75
UE 14	CY	CI	M1	F	>50
UE 21	CY	CI	M3	M	50-60
UE 22	CY	CI	M1	M	20
UE 25	CY	SA	M1	M	50-60
UE 26	CY	SA	No	M	50-60
UE 54	CY	CI	M2	M	>50
UE FII-I	NH	SG	No	M	41-45
UE 108	NH	SG	P2	M	>60
UE 114	NH	SG	P2	M	41-50
UE 117	NH	SG	No	M	>20
UE 125	NH	SG	P1	M	50-55
UE 134	NH	No data	No	M	>20
SS F III	LF	SG	No	M	30-34
UE 208	LF	SG	No	M	41-50
UE 221-224	LF	SG	No	M	41-45
UE 242	LF	SG	No	M	>50
UE 245	LF	SG	No	M	41-50
UE 251	LF	SG	No	F	25-34
UE 258	LF	SG	No	F	50-60
UE 262	LF	SG	No	M	20
UE 265	LF	SG	No	M	50-60
UE 270	LF	SG	No	M	45-50
T11 G2-I	GR	CI	I2	M	40-45
UE 1005	GR	SA	No	M	20-49
UE 1006	GR	SA	M3	M	>20
UE 3006	GR	SA	C1	F	40-44
UE 9004	GR	SA	No	F	45-60
UE 13004	GR	CI	M2	M	30-40

Table 2. Considered entheses divided according to their functional complex.

Entheses	Functional complex
Costoclavicular ligament (clavicle) Conoid ligament (clavicle) Trapezoid ligament (clavicle) Pectoralis major muscle (clavicle) Deltoideus muscle (clavicle) Pectoralis major muscle (humerus) Latissimus dorsi / teres major muscle (humerus) Deltoideus muscle (humerus)	Shoulder
Triceps brachii muscle (scapula) Brachioradialis muscle (humerus) Biceps brachii muscle (radius) Triceps brachii muscle (ulna) Brachialis muscle (ulna)	Elbow (flexion/extension)
Pronator teres muscle (radius) Interosseous membrane (radius) Supinator muscle (ulna)	Forearm (pronation/supination)
Gluteus maximus muscle (femur) Iliopsoas muscle (femur).	Hip
Vastus medialis muscle (femur) Quadriceps tendon (tibia) Quadriceps tendon (patella)	Knee
Soleus muscle (tibia) Achilles tendon (calcaneus)	Foot

Table 3. Entheses scored by location.

Entheseal marker	Location
Subscapularis muscle (shoulder)	Lesser tubercle of the humerus
Supraspinatus muscle (shoulder)	Greater tubercle of the humerus (anteroproximal facet)
Infraspinatus muscle (shoulder)	Greater tubercle of the humerus (posteroproximal facet)
Teres minor muscle (shoulder)	Inferior facet on greater tuberosity of humerus
Anconeus muscle (elbow)	Lateral aspect the olecranon extending to the lateral surface of the ulnar body
Brachialis muscle (elbow)	Anterior surface of ulnar coronoid processs
Triceps brachii muscle (elbow)	Olecranon posterior surface
Biceps brachii muscle (elbow)	Radial bicipital tuberosity
Brachioradialis muscle (wrist/hand)	Styloid process of the radius
Common origin of wrist extens. (wrist/hand)	Lateral epicondyle of the humerus
Common origin of wrist flexor (wrist/hand)	Medial epicondyle of the humerus
Gluteus medius muscle (hip)	Greater trochanter of the femur
Iliopsoas muscle (hip)	Lesser trochanter of the femur
Gluteus minimus muscle (hip)	Greater trochanter of the femur
Semimembranosus muscle (hip)	Posterior facet of the medial condyle of tibia
Popliteus muscle (knee)	Posterior surface of tibia below condyles
Triceps surae muscle (ankle)	Calcaneal tuberosity

Table 4. $^{87}Sr/^{86}Sr$ isotope ratios in human and domestic faunal skeletal tissue found at the San Andrés de Arroyo Monastery. Uncertainty is given as standard deviation (s.d.).

	Bone		Teeth	
Specimen number	$^{87}Sr/^{86}Sr$	s.d.	$^{87}Sr/^{86}Sr$	s.d.
Human remains				
UE 8	0.70875	0.00006	0.70882	0.00005
UE 14	0.70878	0.00006	0.70917	0.00008
UE 21	0.70931	0.00006	0.70951	0.00009
UE 22	0.70894	0.00006	0.70948	0.00010
UE 25	0.70884	0.00005	0.70937	0.00012
UE 26	0.70888	0.00006	-	-
UE 54	0.70895	0.00005	0.70911	0.00008
UE FII-I	0.70869	0.00009	-	-
UE 108	0.70893	0.00006	0.71234	0.00008
UE 114	0.70946	0.00005	0.71084	0.00012
UE 117	0.70892	0.00012	-	-
UE 125	0.70895	0.00008	0.70967	0.00008
UE 134	0.70874	0.00005	-	-
SS F III	0.70893	0.00005	-	-
UE 208	0.70864	0.00006	-	-
UE 221-224	0.70869	0.00006	-	-
UE 242	0.70869	0.00007	-	-
UE 245	0.70902	0.00007	-	-
UE 251	0.70921	0.00007	-	-
UE 258	0.70891	0.00007	-	-
UE 262	0.70891	0.00007	-	-
UE 265	0.70945	0.00006	-	-
UE 270	0.70892	0.00006	-	-
T11 G2-I	0.70903	0.00008	0.70946	0.00004
UE 1005	0.70933	0.00008	-	-
UE 1006	0.70911	0.00008	0.70937	0.00008
UE 3006	0.70895	0.00006	0.70868	0.00007
UE 9004	0.70914	0.00009	-	-
UE 13004	0.70888	0.00007	0.70886	0.00003
Animal remains				
S-B 01	0.70881	0.00006	-	-
S-B 02	0.70898	0.00006	-	-
S-B 03	0.70871	0.00007	-	-
S-B 04	0.70901	0.00006	-	-
S-B 05	0.70861	0.00005	-	-
C-B 01	0.70889	0.00008	-	-
S-T 01	-	-	0.70890	0.00006

Table 5. Possible labour-related activities (based on the musculoskeletal markers observed) for all the individuals subjected to analysis.

Specimen number	Sex	Age	Occupational category (adapted from Villotte et al. 2010)	Examples of possible labour-related activities
UE 8	M	50-75	B	Woodcutter, harvester, farmer
UE 14	F	>50	A	Farmer, weaver, walks through rough terrains
UE 21	M	50-60	B	Carpenter, tanner, walks through rough terrains
UE 22	M	20	-	No data
UE 25	M	50-60	B	Carpenter, woodcutter, blacksmith, walks through rough terrains
UE 26	M	50-60	B	Farmer, woodcutter
UE 54	M	>50	B	Farmer, long walks
UE FII-I	M	41-45	B	Stockbreeder, farmer, bricklayer, walks through rough terrains, long walks
UE 108	M	>60	B/C	Blacksmith, stone sculpting, riding, military activities
UE 114	M	41-50	B/C	Woodcutter, stone sculpting, metalworking, archery, warfare activities
UE 117	M	>20	-	No data
UE 125	M	50-55	A/B	Stockbreeder, farmer, walks through rough terrains
UE 134	M	>20	-	No data
SS F III	M	30-34	B	Farmer, woodcutter, walks through rough terrains
UE 208	M	41-50	B	Woodcutter, blacksmith, carpenter, tanner
UE 221-224	M	41-45	B	Stonemason, farmer, blacksmith, walks through rough terrains
UE 242	M	>50	A/B	Craftsman, woodcutter, tanner, walks through rough terrains
UE 245	M	41-50	B	Stockbreeder, shepherd, farmer, long walks
UE 251	F	25-34	A/B	Craftsman, seamstress, weaver
UE 258	F	50-60	A	Weaver, long walks
UE 262	M	20	-	No data
UE 265	M	50-60	B	Woodcutter, blacksmith, tanner, walks through rough terrains, long walks

UE 270	M	45-50	B	Miller, bricklayer, rider
T11 G2-I	M	40-45	A	Farmer, weaver
UE 1005	M	20-49	B	Farmer, stonemason, carpenter
UE 1006	M	>20	A	Farmer
UE 3006	F	40-44	A	Farmer, weaver
UE 9004	F	45-60	A	Farmer, weaver, washerwoman
UE 13004	M	30-40	B	Craftsman, long walks

Table 6. Entheseal Changes (EC) observed in the individuals defined as locals according to the strontium isotope data. Right (R) and left (L) markers are presented for each individual. EF means enthesophytic formation. Classes: 0 = absence; 1 = minimal exostosis (< 1 mm); 2 = clear exostosis (1-4 mm); 3 = substancial exostosis (> 4mm); NR means that more than 50% of the area is illegible.

OL means osteolytic formation. Classes: 0 = absence; 1 = fine porosity (holes < 1 mm); 2 = gross porosity (holes ~ 1 mm), or small area of erosion (~ 4 mm), or extensive and deep osteolytic area (> 4 mm); 3 = several small areas of erosion (~ 4 mm) or extensive and deep osteolytic area (> 4 mm), NR means that more than 50% of the area is illegible.

Entheseal marker	UE8		UE14		UE21		UE25		UE26		UE54		UE FII-I		UE108		UE114	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Subscapularis muscle	EF1	0	EF1	EF1	EF1	EF1	0	0	EF1	0	EF2	0	EF1	EF1	0	EF1	EF2	0
Supraspinatus muscle	OL3	OL1	OL2	OL1	OL2	NR	OL2	OL2	OL3	OL2	NR	OL1	OL3	NR	0	OL1	OL1	0
Infraspinatus muscle	EF2	EF2	EF2	EF1	NR	NR	EF2	EF2	0	0	NR	EF2	0	0	EF1	EF2	EF1	EF1
Teres minor muscle	OL1	0	0	0	NR	NR	OL1	OL1	OL1	OL1	NR	0	0	NR	0	0	OL1	OL1
Anconeus muscle	OL2	OL1	OL1	OL1	OL2	OL2	OL2	OL2	OL1	OL1	0	0	0	0	OL2	OL1	0	OL2
Brachialis muscle	EF2	EF1	NR	NR	0	0	EF1	EF1	EF1	EF1	EF1	EF1	0	0	OL1	OL1	EF1	EF1
Triceps brachii muscle	EF2	EF1	0	0	EF2	EF2	EF2	EF1	EF1	EF1	0	0	0	0	EF1	EF3	EF3	EF1
Biceps brachii muscle	EF1	EF1	EF1	OL1	EF2	OL2	EF2	EF2	EF1	EF1	EF2	EF1	0	0	EF2	EF2	0F2	EF2
Brachioradialis muscle	EF2	EF2	EF2	EF2	0	0	0	EF2	EF2	EF1	EF2	EF2	0	0	EF1	EF1	EF1	0
Common origin of wrist extensors	0	0	EF1	0	0	0	0	EF1	0	0	0	0	0	0	EF3	EF2	EF2	EF2
Common origin of wrist flexor	0	0	0	0	0	0	EF1	0	0	0	0	0	0	0	EF2	EF1	0	0
Gluteus medius muscle	EF2	EF2	EF1	EF1	EF1	EF1	EF2	EF2	0	0	EF2	EF2	0	0	EF2	EF3	EF1	0
Iliopsoas muscle	EF1	EF1	EF2	EF1	EF2	EF2	EF2	EF2	EF2	EF2	NR	EF1	0	0	NR	EF2	EF2	EF2
Gluteus minimus muscle	EF1	EF1	EF2	EF1	EF1	EF1	EF2	EF2	0	0	EF2	EF2	0	0	EF2	EF2	NR	EF2
Semimembranosus muscle	EF1	EF1	0	0	0	NR	EF2	EF2	0	0	0	0	0	0	EF1	EF2	EF2	NR
Popliteus muscle	EF1	EF1	EF1	EF1	0	0	EF2	EF2	EF1	EF1	0	0	0	0	EF1	EF2	EF1	0
Triceps surae muscle	EF3	EF2	EF2	EF2	EF3	EF3	NR	NR	EF2	EF3	EF3	EF3	EF1	EF1	EF2	EF2	EF2	EF2

Entheseal marker	UE 125		SS F III		UE 208		UE221-224		UE 242		UE 245		UE 251		UE 258	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Subscapularis muscle	0	0	0	NR	EF1	EF1	0	0	EF1	EF1	0	0	EF1	EF1	EF1	EF1
Supraspinatus muscle	OL3	OL1	OL3	NR	EF2	EF2	OL3	OL3	0	0	OL2	OL2	EF1	0	EF1	EF1
Infraspinatus muscle	EF2	0	OL2	NR	EF2	EF2	OL2	0	EF2	EF2	EF2	EF2	EF2	EF2	EF2	EF1
Teres minor muscle	0	OL1	0	NR	OL2	OL1	0	0	NR	0	OL1	OL1	OL1	OL1	OL1	NR
Anconeus muscle	0	0	OL2	NR	OL2	OL2	OL2	OL2	OL2	OL1	OL2	NR	OL2	0	OL2	0
Brachialis muscle	EF1	EF1	0	0	EF2	EF1	0	0	OL1	OL2	OL2	0	NR	EF2	NR	EF1
Triceps brachii muscle	0	0	EF2	EF1	EF3	EF1	EF2	EF2	EF1	EF1	EF2	0	EF2	EF1	EF2	EF2
Biceps brachii muscle	EF2	EF2	EF2	0	EF2	EF1	0	0	EF1	EF1	EF2	NR	EF1	0	EF1	EF1
Brachioradialis muscle	EF2	EF2	EF3	NR	EF2	EF2	EF1	EF2	EF2	EF1	EF2	NR	NR	EF1	EF1	EF1
Common origin of wrist extensors	0	0	EF1	0	0	0	0	0	EF1	0	NR	NR	0	NR	0	0
Common origin of wrist flexor	0	0	0	0	EF1	0	0	0	0	0	0	0	0	EF1	EF1	0
Gluteus medius muscle	EF2	EF2	0	0	EF2	EF2	EF2	EF2	EF1	NR	EF2	EF2	0	0	0	0
Iliopsoas muscle	0	0	0	0	EF2	EF2	EF2	EF2	EF2	NR	0	0	0	0	0	0
Gluteus minimus muscle	EF2	EF1	0	0	EF3	EF2	EF2	EF2	EF1	NR	EF2	EF2	0	0	0	0
Semimembranosus muscle	0	0	NR	0	EF2	EF2	0	0	0	0	0	0	0	0	0	0
Popliteus muscle	0	0	NR	0	EF2	EF2	0	0	EF2	EF2	EF2	EF2	0	0	NR	0
Triceps surae muscle	EF2	EF2	EF1	NR	EF2	EF2	EF2	NR	EF2	EF2	EF2	EF2	EF1	EF1	EF2	EF1

Entheseal marker	UE 265		UE 270		T11 G2-I		UE 1005		UE 1006		UE 3006		UE 9004		UE 13004	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
Subscapularis muscle	0	0	0	0	0	0	0	0	O	NR	EF1	EF1	0	0	EF1	EF1
Supraspinatus muscle	0	0	0	0	OL2	OL2	OL3	OL3	OL3	NR	OL2	OL1	OL2	OL2	OL2	OL1
Infraspinatus muscle	EF1	EF1	EF1	EF1	EF1	EF1	EF1	EF1	EF1	NR	EF1	EF1	EF1	0	EF2	EF2
Teres minor muscle	0	0	0	0	NR	0	OL1	OL1	0	0	0	0	0	0	OL2	OL1
Anconeus muscle	OL2	0	0	0	NR	OL1	0	0	NR	0	0	0	0	0	OL2	OL2
Brachialis muscle	EF2	EF2	EF2	EF1	EF1	EF2	EF1	EF1	NR	0	EF3	EF3	EF2	EF2	EF2	EF1
Triceps brachii muscle	EF2	EF2	EF3	EF3	0	EF1	EF2	EF1	NR	0	EF1	EF1	EF1	NR	EF3	EF2
Biceps brachii muscle	EF2	0	EF1	EF2	EF1	EF1	EF1	0	EF2	EF2	EF2	EF2	EF1	EF2	EF2	EF1
Brachioradialis muscle	EF2	0	0	0	NR	0	0	0	EF2	NR	EF2	EF1	EF2	EF1	0	0
Common origin of wrist extensors	0	0	NR	NR	0	0	EF2	0	0	0	EF1	0	0	0	0	0
Common origin of wrist flexor	EF1	0	0	0	0	0	0	EF1	0	0	EF1	EF1	0	0	EF1	0
Gluteus medius muscle	0	0	EF2	EF2	EF2	EF1	EF1	EF1	EF2	EF1	EF2	EF2	0	0	0	0
Iliopsoas muscle	NR	EF1	EF1	EF2	0	0	EF2	EF1	EF1	EF1	0	EF3	EF2	EF1	0	0
Gluteus minimus muscle	0	0	EF2	EF2	EF2	EF1	EF2	EF2	EF1	EF1	EF2	EF2	0	0	0	0
Semimembranosus muscle	EF1	0	0	0	EF2	0	0	0	EF1	EF1	NR	0	EF2	0	EF1	0
Popliteus muscle	EF3	EF2	EF2	0	EF3	EF3	0	0	0	0	NR	0	EF2	0	0	0
Triceps surae muscle	EF2	EF2	EF2	EF2	EF1	EF1	NR	NR	EF2	EF2	EF1	NR	EF2	EF2	EF1	EF1